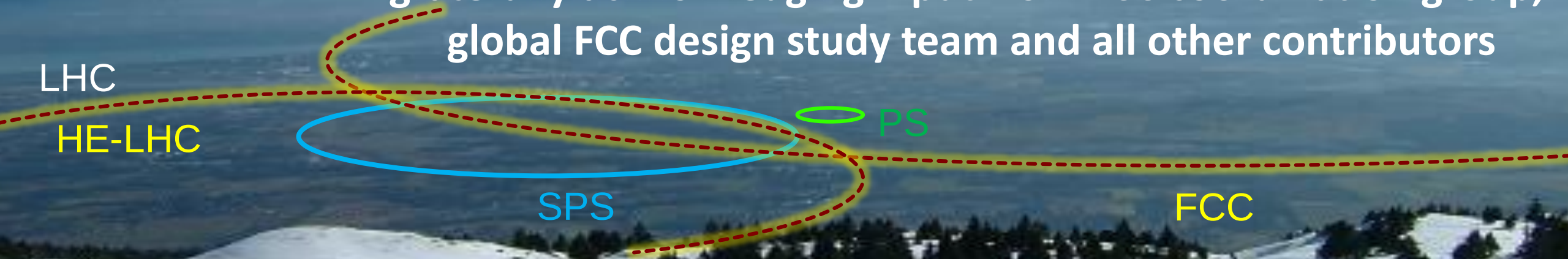
Future Circular Collider Study

The global project: civil engineering, implementation plan, schedules, costs, next steps

M. Benedikt

gratefully acknowledging input from FCC coordination group, global FCC design study team and all other contributors



http://cern.ch/fcc

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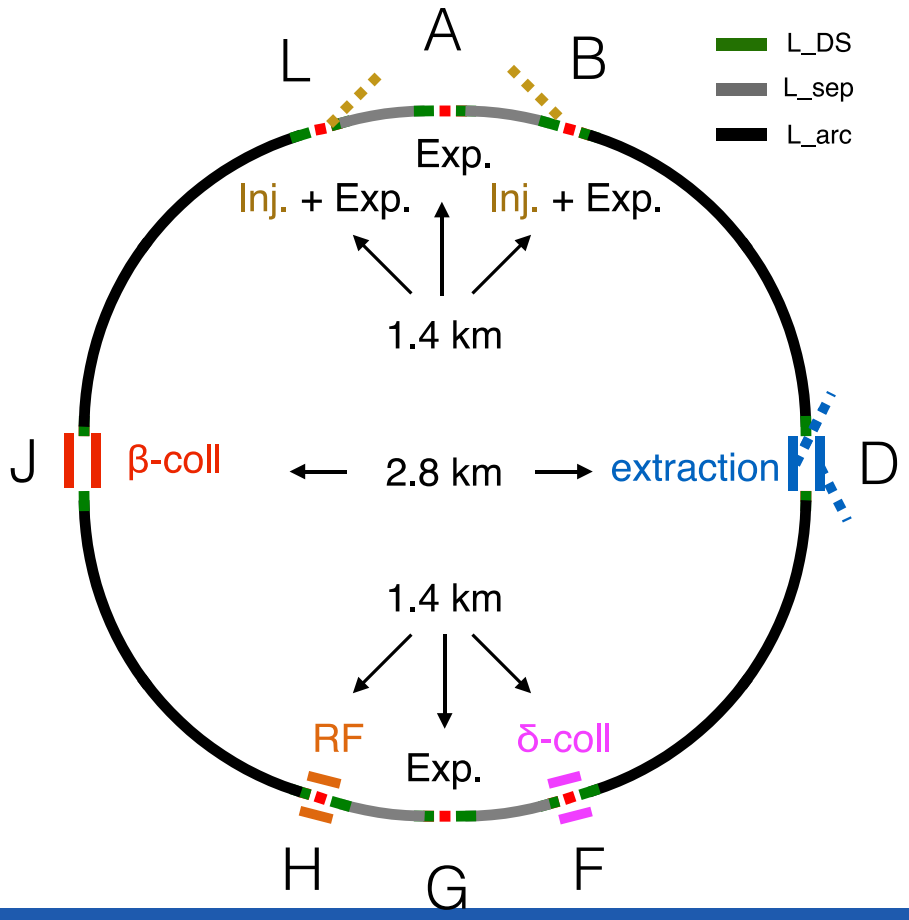
photo: J. Wenninger

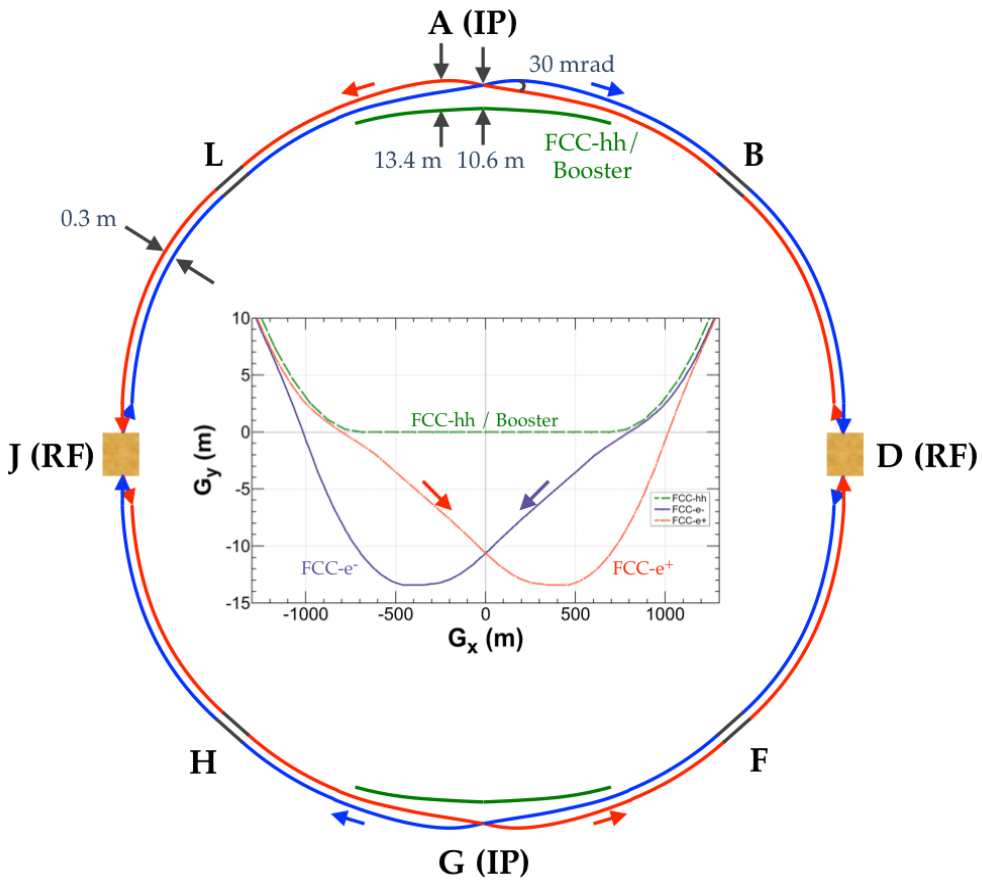
FCC-common layouts

FCC-hh

- **Common footprint except around IPs**
- **Asymmetric IR layout** to limit synchrotron radiation

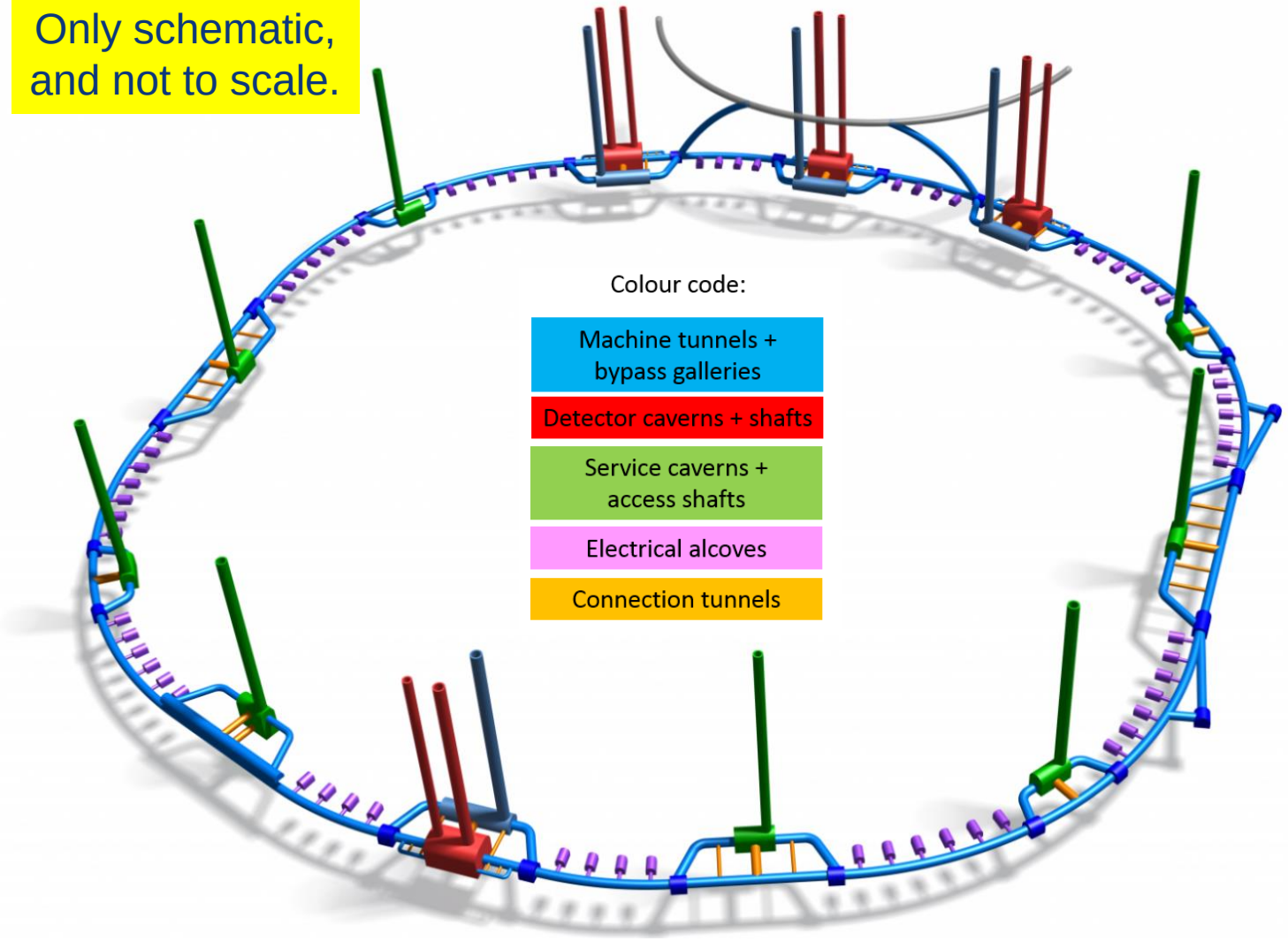
FCC-ee





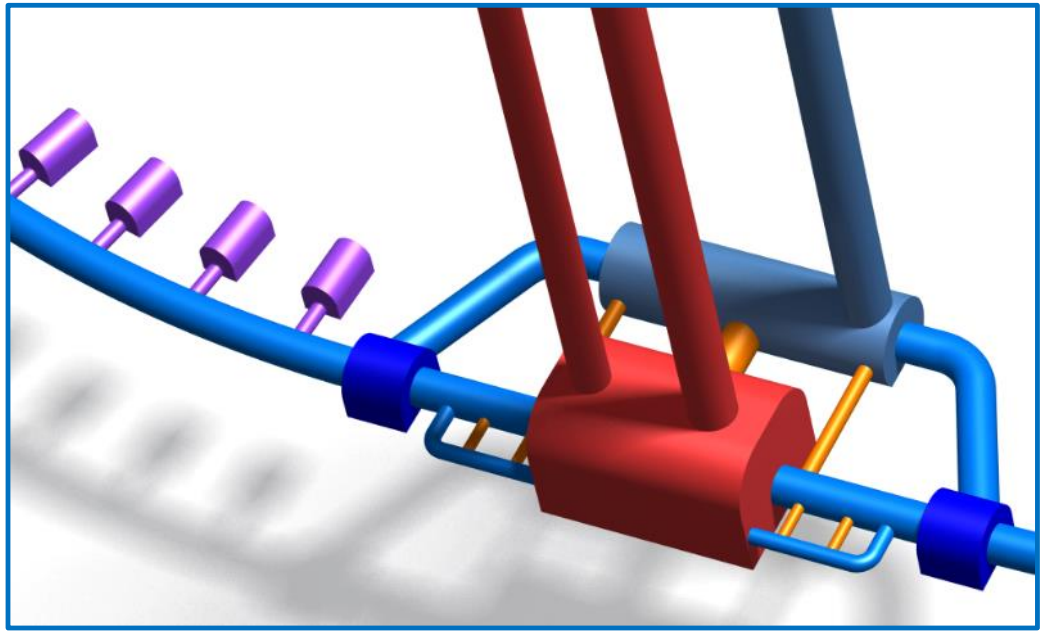
Underground Structures

Only schematic, and not to scale.



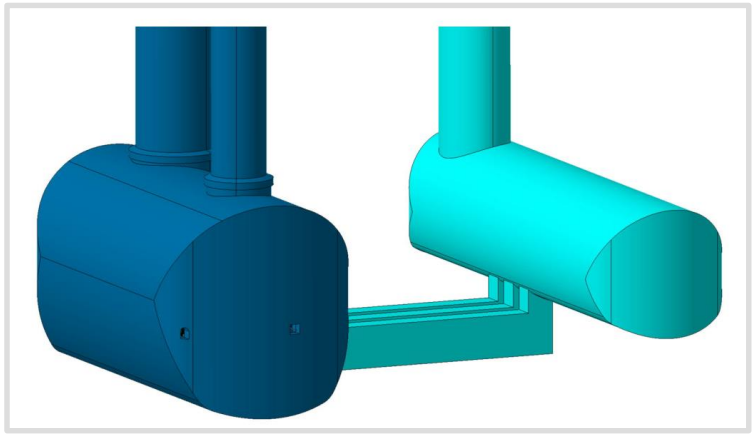
All structures based on most stringent requriements FCC-ee/FCC-hh

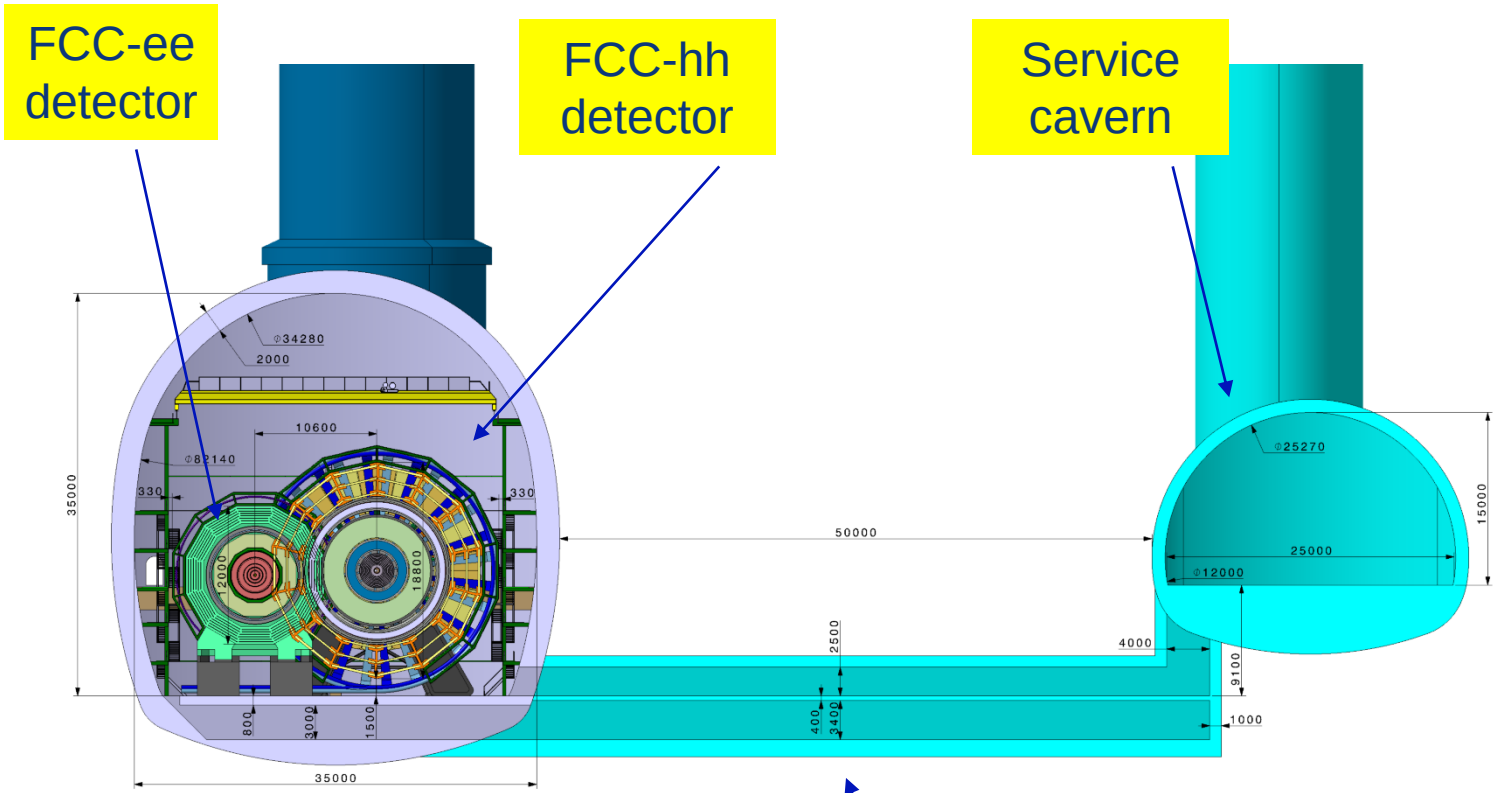
Experiment cavern structures (e^+e^- enlargements not shown)



Common experimental points (A, G)

Distance between detector cavern and service cavern 50 m.
Strayfield of unshielded detector solenoid < 5mT.





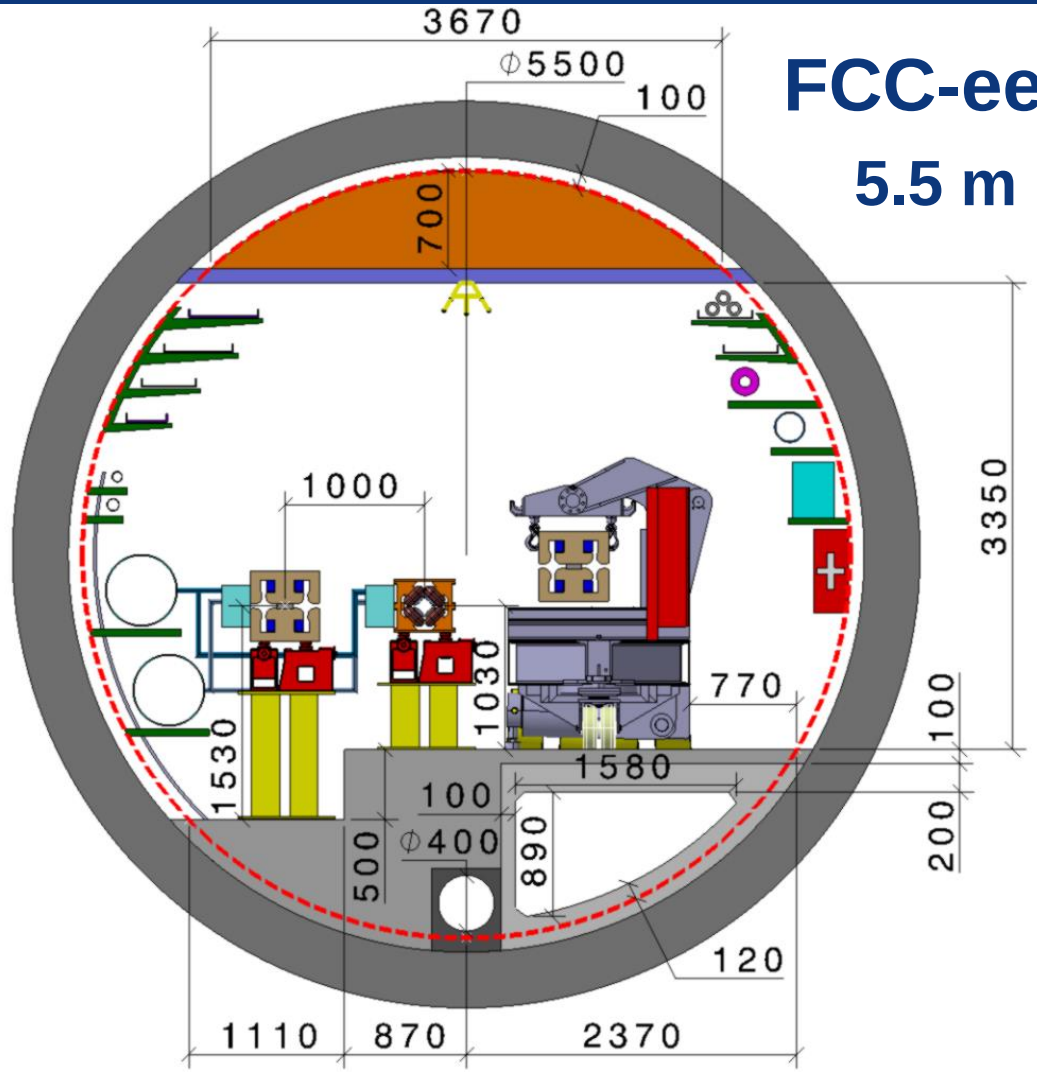
Preliminary design of access and cable paths

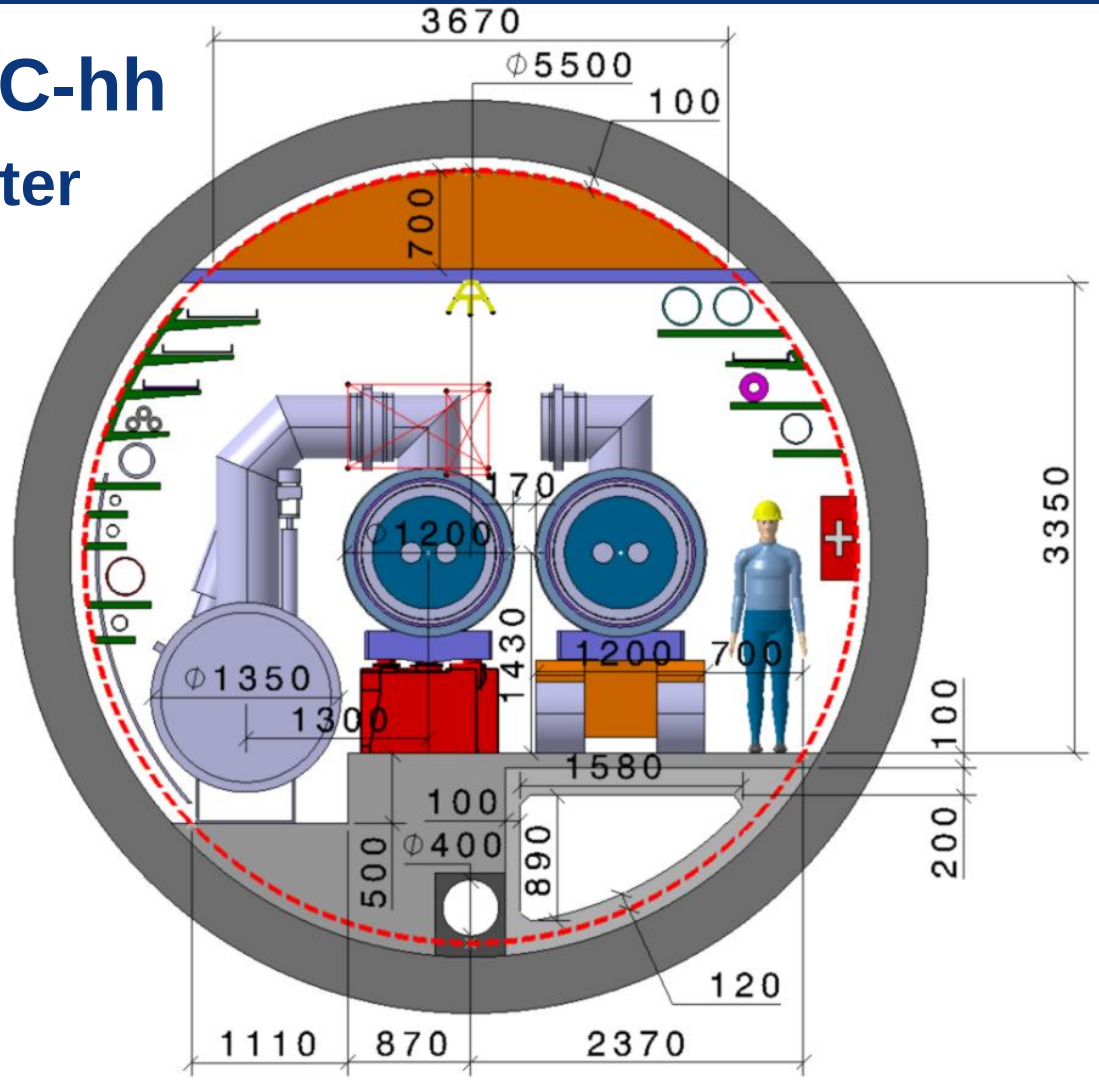
Tunnel integration in arcs

FCC-ee

FCC-hh

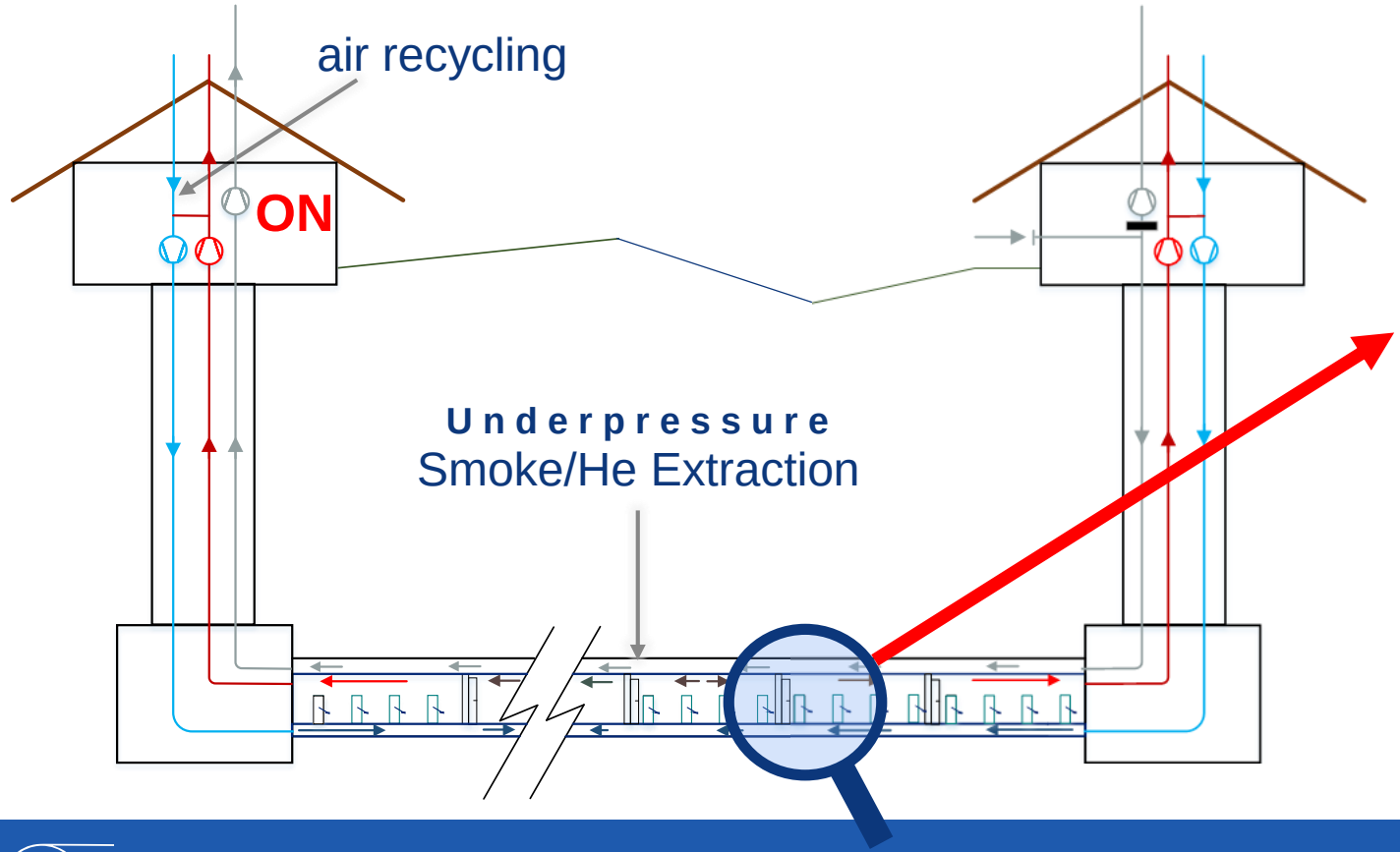
5.5 m inner diameter

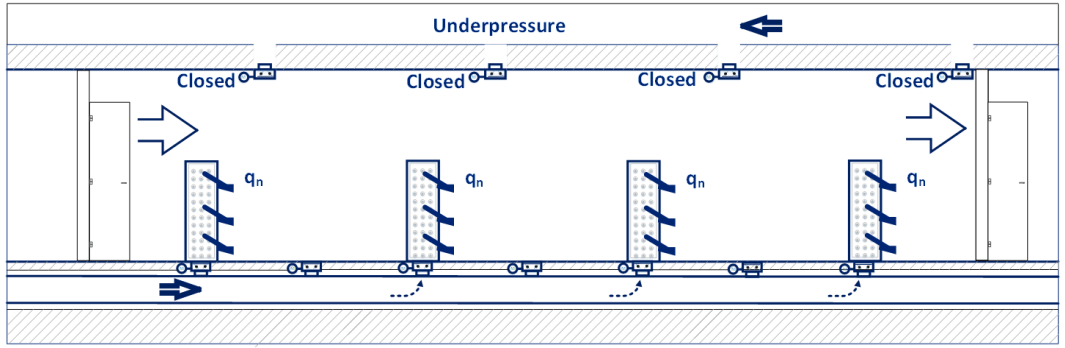


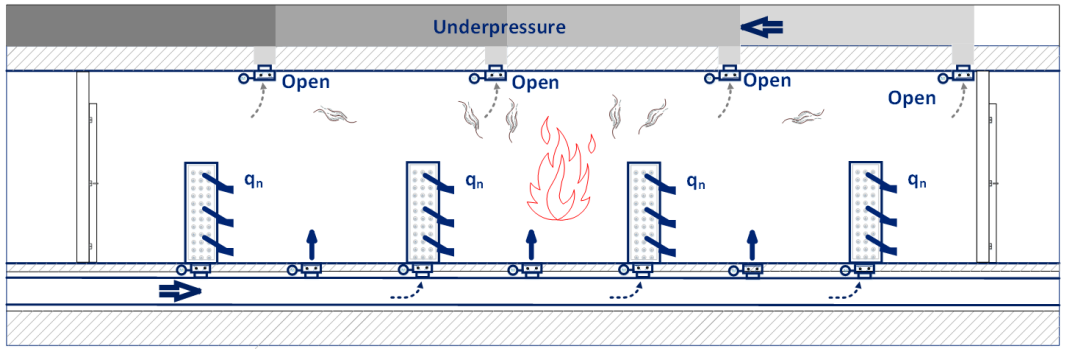


Ventilation system – Safety concept

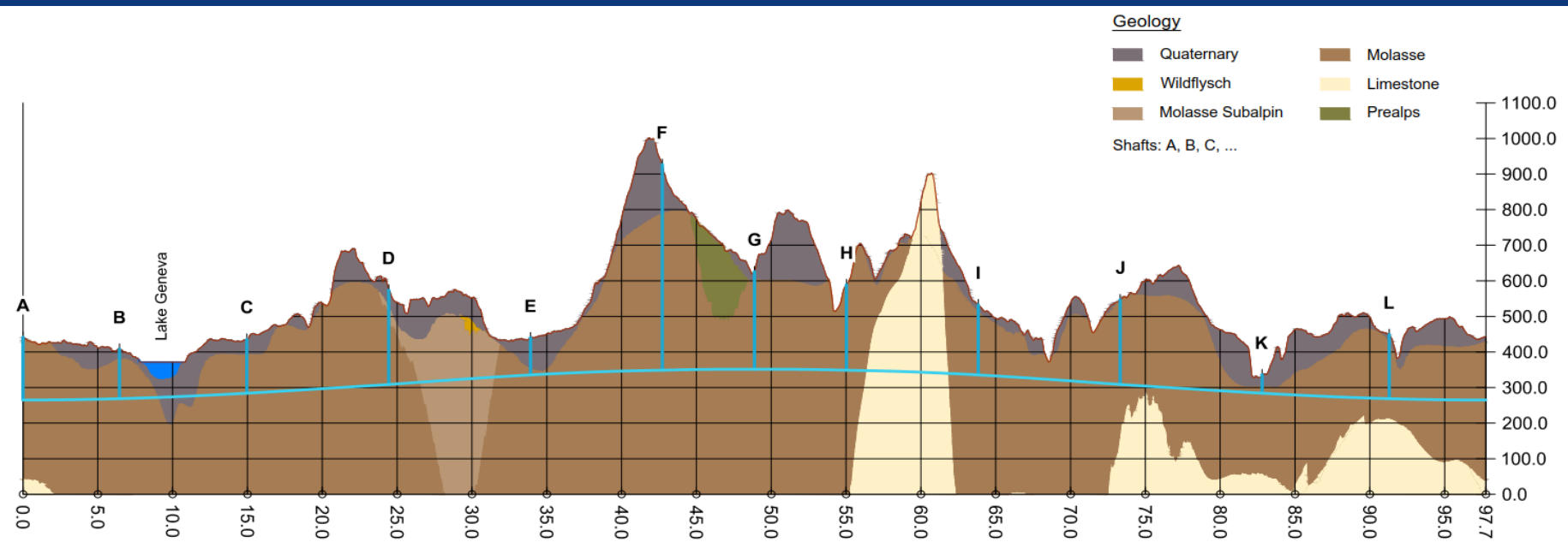
Air injection and extraction systems on each point with full air recycling, (contrary to LHC)
Longitudinally separated compartments to allow isolation in case of fire/He leak, etc.
e.g. one side extraction fan will be ON, underpressurising the extraction duct, for fast reaction in case of emergency

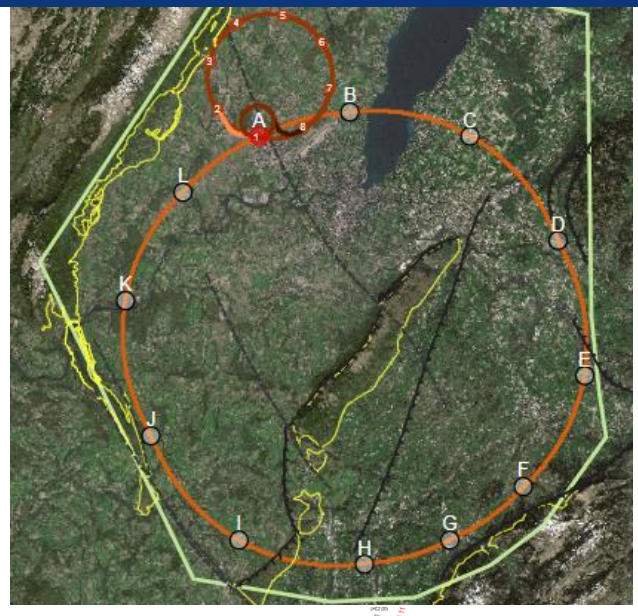


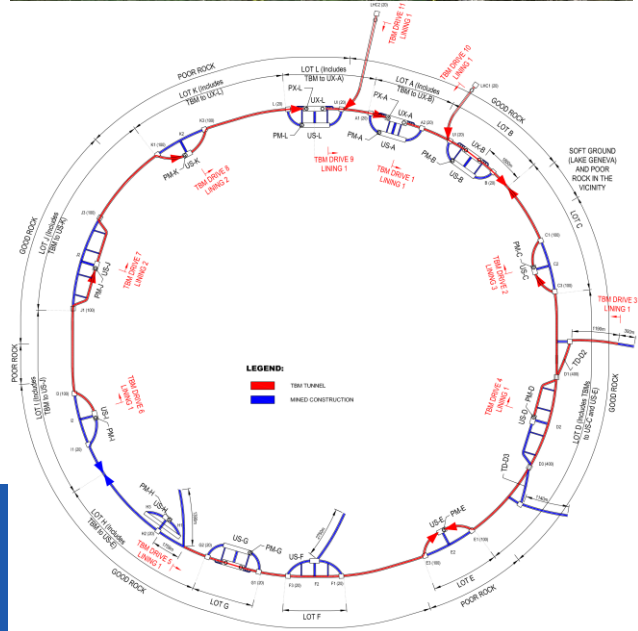




FCC implementation - footprint baseline





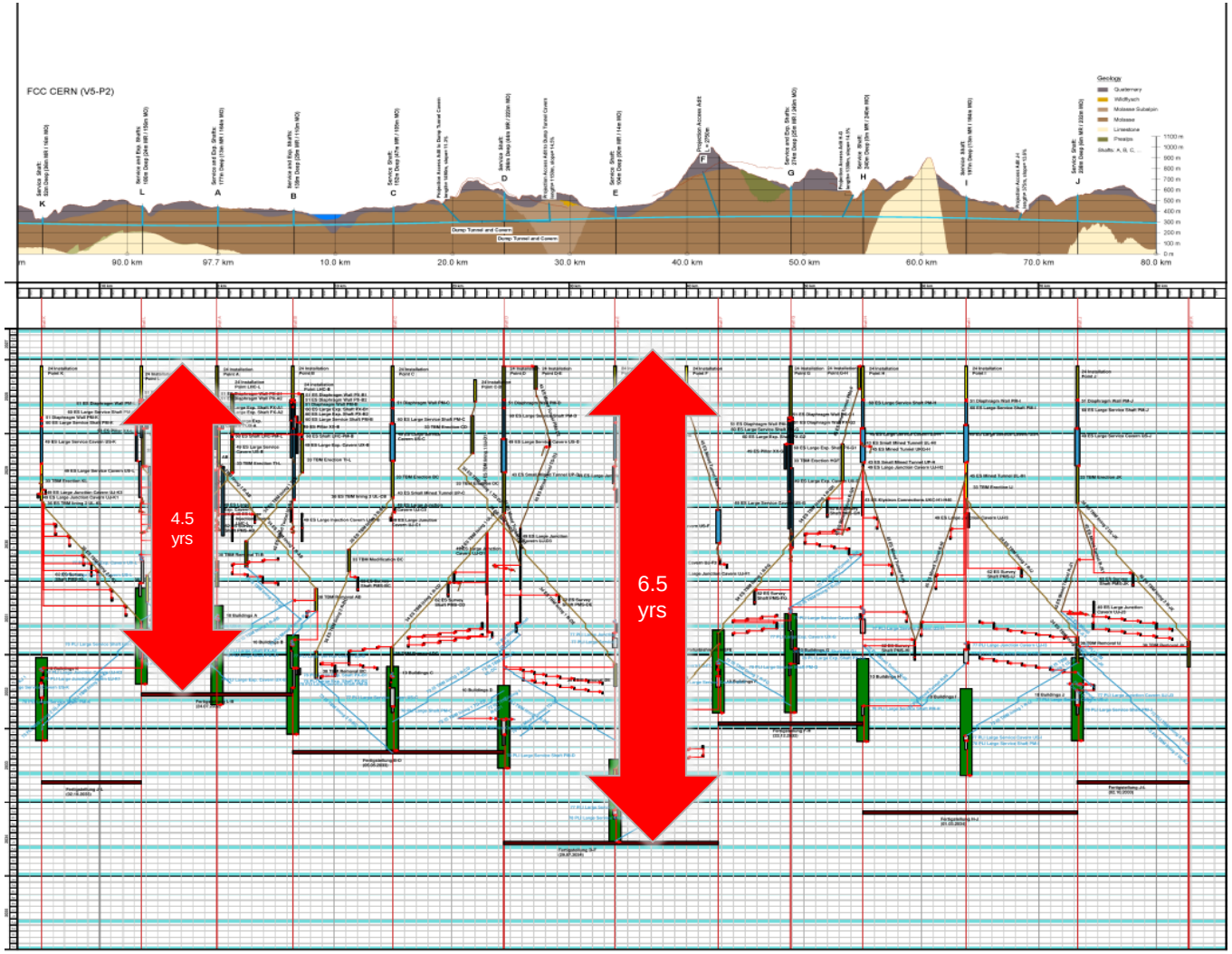


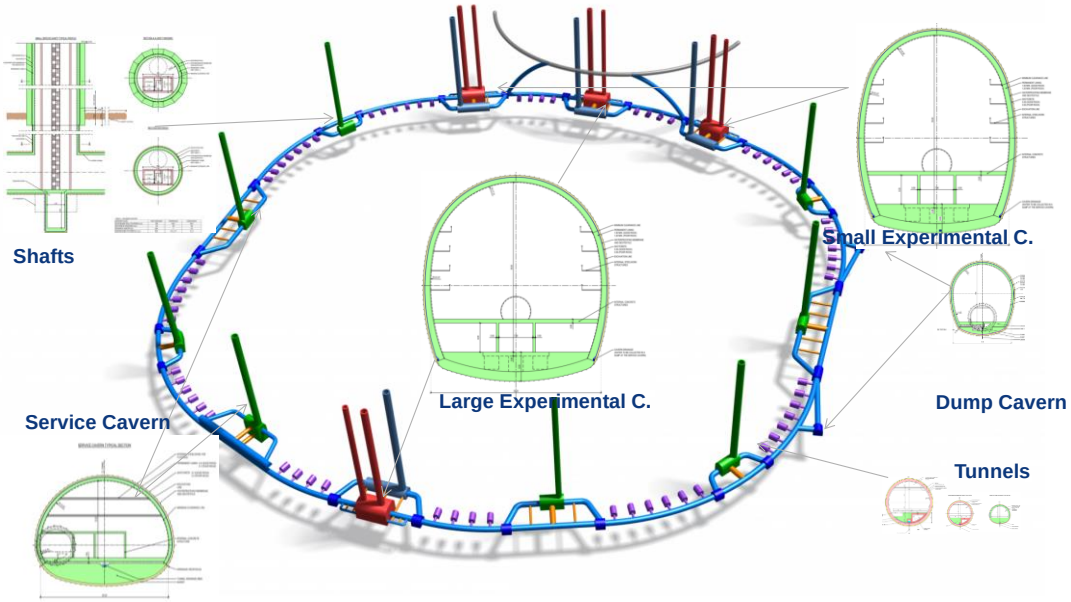
Present baseline position was established considering:

- lowest risk for construction
- fastest and cheapest construction
- feasible positions for large span caverns (most challenging structures)

next step: review of surface site locations and machine layout

CE schedule studies

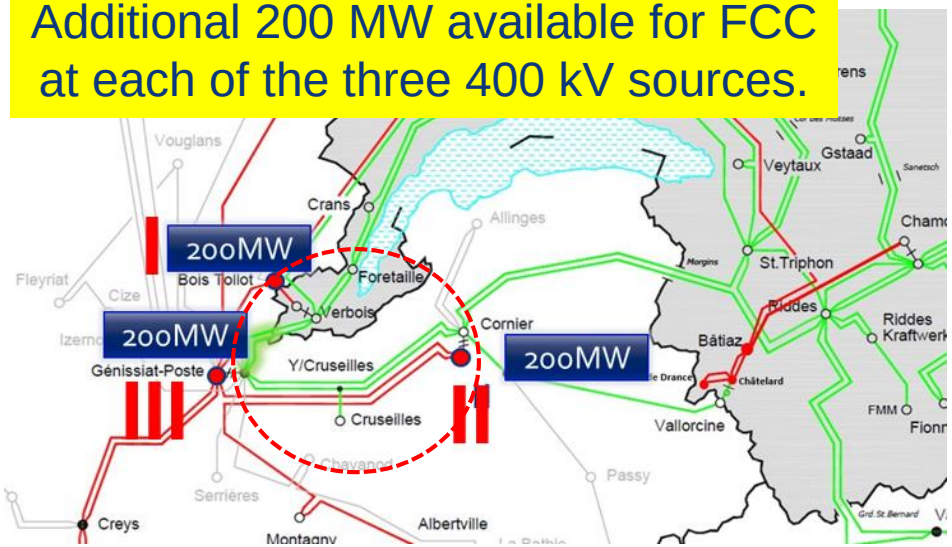




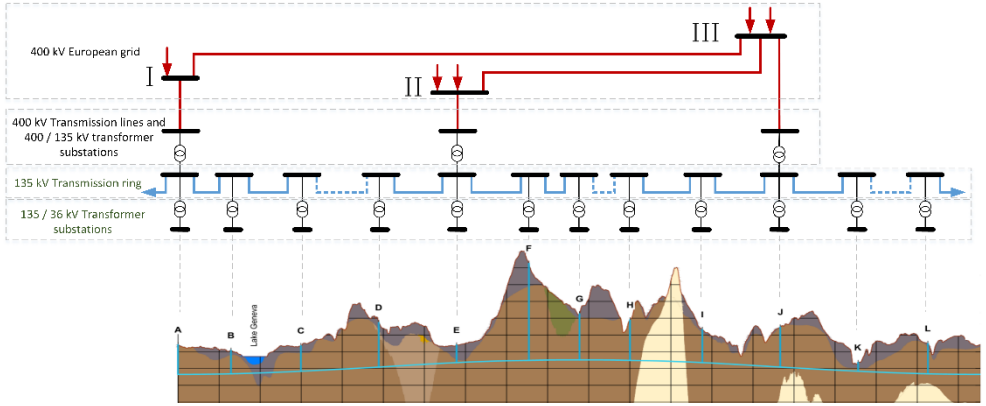
- **Total construction duration 7 years**
- **First sectors ready after 4.5 years**

Supply and distribution of electrical energy

Additional 200 MW available for FCC at each of the three 400 kV sources.

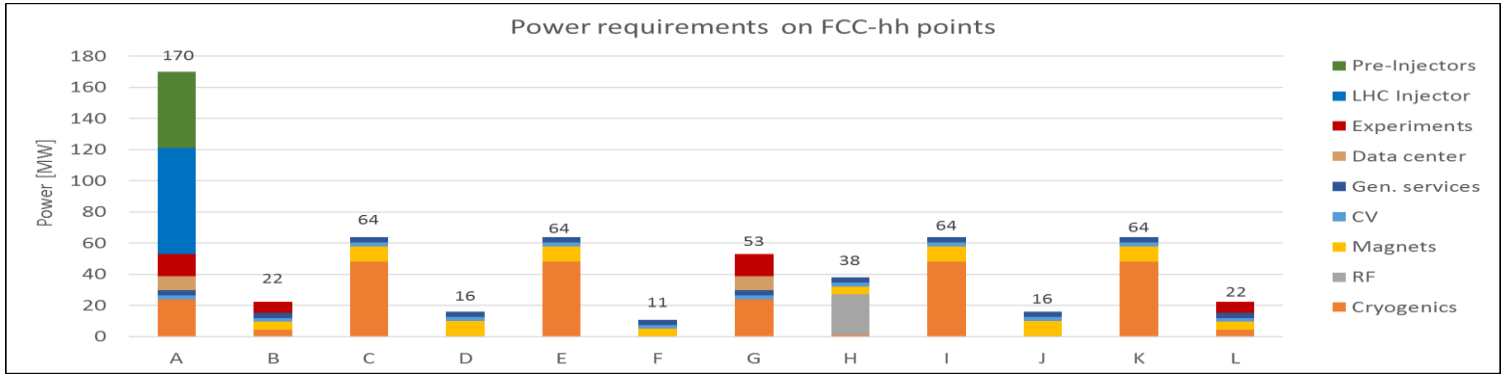


---- 400 kV ---- 230 kV

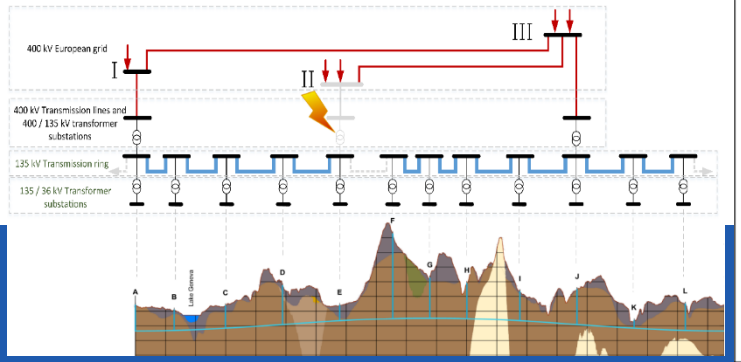


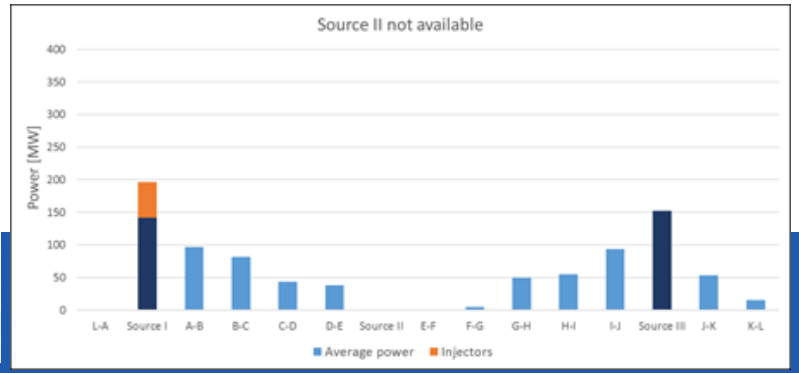
3 x 400 kV connections
+ 135 kV underground power distribution (NC)

Per-point power requirements as input for infrastructure-optimized conceptual design. (Peak FCC-ee 260 - 340 MW, total FCC-hh 550 MW)



If one power source goes down fall back to „degraded mode“: FCC remains cold, vacuum preserved, controls on, RF off, no beam (“standby”). All FCC points supplied from 2 other 400 kV points, through the power transmission line.





FCC work with Host States

General secretariat of the region Auvergne-Rhône-Alpes
and notified body “Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement” CEREMA

Working group with representatives of federation, canton and state of Geneva and representation of Switzerland
at the international organisations and consultancy companies

- Administrative processes for project preparatory phase developed.
- First review of tunnel placement performed.
- Requirements for urbanistic, environmental, economic impact, land acquisition and construction permit related processes defined.
- **For 2019-20, common optimization of collider tunnel and surface site infrastructure implementation planned.**

Preliminary site reviews

In partnership with a Geneva based environmental consulting company (for CH part) + a government operated body (for F part)
- **preliminary reviewed and assessed the surface sites, underground volumes, infrastructure needs**
- **analysed the required next steps and schedule considerations**
- analysed the development potential and opportunities (socio-economic benefits)

Aim:
- **understand applicable methods in host states, legal and regulatory constraints**
- **understand whether a 100 km tunnel and surface infrastructure as feasible from a socio-urbanistic perspective**
- determine whether an integrated and uniform method can be adopted for a subsequent design phase

Description


PRELIMINARY LAYOUT REVIEW

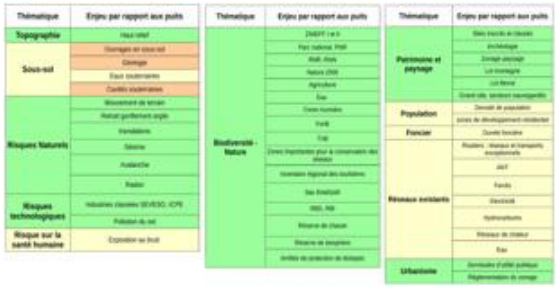
FCC

Future Circular Collider Study

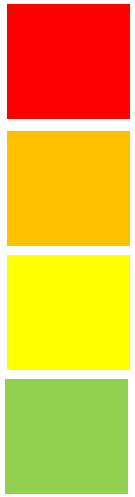
DOCUMENT TYPE

PRELIMINARY LAYOUT REVIEW

Applicable criteria



Classification



Mitigation

Principle FCC feasibility in region confirmed

Iterative optim. process shown to be efficient (6 months „turn-around“)

Socio-economic benefits identified, examples:
- networks and infrastructure development
- energy recovery/waste heat use
- education and training facilities

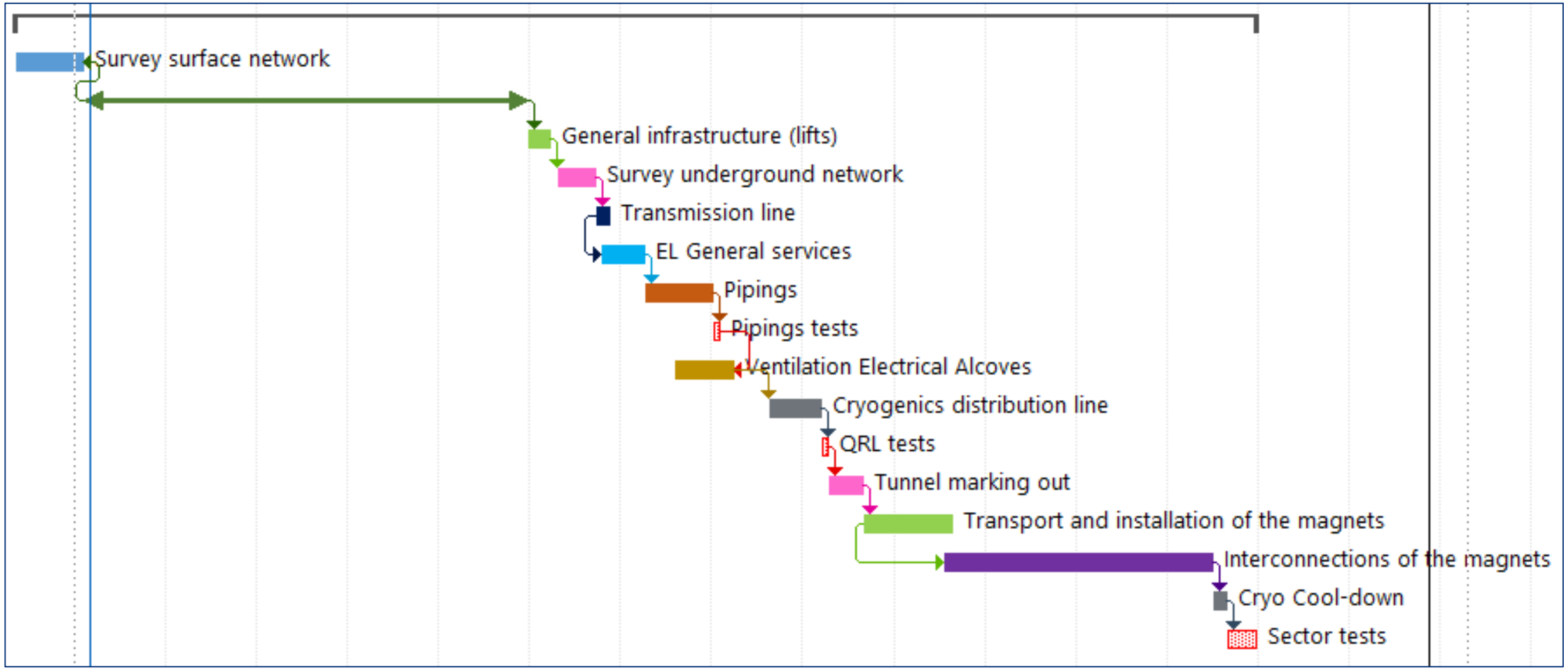
Recommendations on
- ground analysis procedures
- schedule development

Input to schedule studies

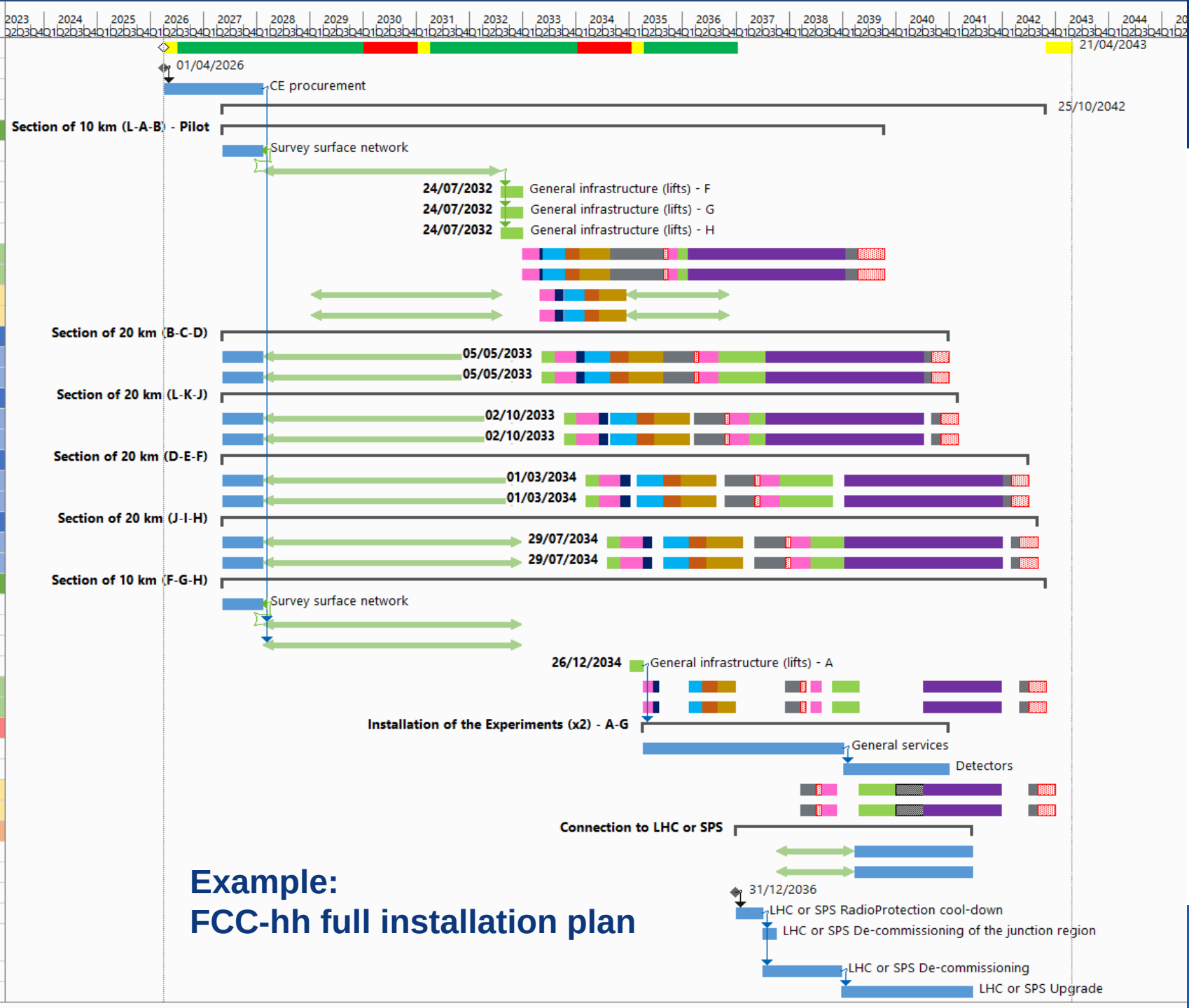
- Results of discussions with host state authorities for definition of preparatory phase duration
- Present CERN procurement rules for duration of tendering and adjudication phases
- CE consultants input for duration of various planning phases, site investigations and CE construction
- Detailed CERN schedule study for FCC-hh, based on experience from LHC, HL-LHC (learning curves, LS1, taking into account number of persons underground, number of crews, structuring of industrial installation contracts, etc.)
- Adaptation to FCC-ee by scaling from FCC-hh study and experience from LEP (e.g. cryo module installation, etc.)

Example of a sector installation sequence

FCC-hh: main elements for sector installation plan

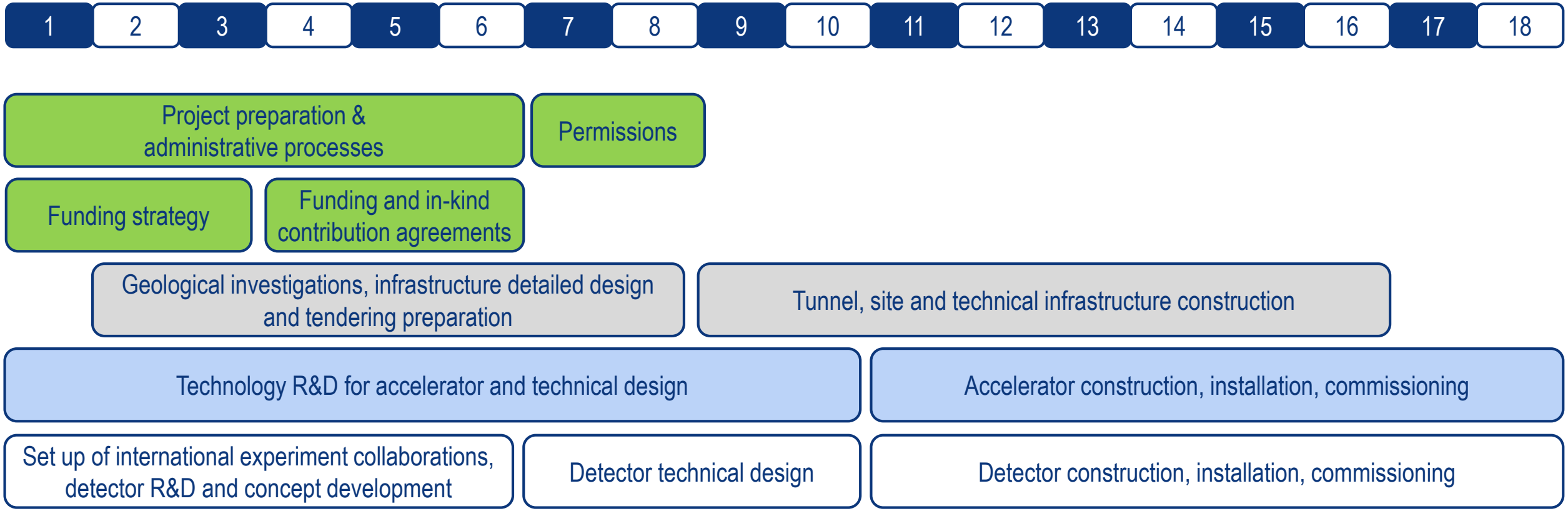


ID	Task Name	Duration	Start	Finish
1	**LHC Operation**	**222.54 mons**	**31/03/26**	**21/04/43**
12	Final decision	0 mons	01/04/26	01/04/26
13	CE procurement	24 mons	01/04/26	01/02/28
14	**FCC_schedule**	**201.8 mons**	**07/05/27**	**25/10/42**
15	**Section of 10 km (L-A-B) - Pilot**	**162.05 mons**	**08/05/27**	**11/10/39**
16	Survey surface network	9 emons	08/05/27	02/02/28
17	Civil Engineering (3 sites, 2 sectors)	58.4 mons	02/02/28	24/07/32
18	General infrastructure (lifts) - F	5 emons	24/07/32	21/12/32
19	General infrastructure (lifts) - G	5 emons	24/07/32	21/12/32
20	General infrastructure (lifts) - H	5 emons	24/07/32	21/12/32
21	**Sector of 5 km (L-A)**	**88.7 mons**	**21/12/32**	**11/10/39**
35	**Sector of 5 km (A-B)**	**88.7 mons**	**21/12/32**	**11/10/39**
49	**Transfer line from B - Phase 1**	**102.8 mons**	**01/01/29**	**17/11/36**
59	**Transfer line from L - Phase 1**	**102.8 mons**	**01/01/29**	**17/11/36**
69	**Section of 20 km (B-C-D)**	**178 mons**	**07/05/27**	**27/12/40**
70	**Sector of 10 km (B-C)**	**178 mons**	**07/05/27**	**27/12/40**
87	**Sector of 10 km (C-D)**	**177.95 mons**	**08/05/27**	**27/12/40**
104	**Section of 20 km (L-K-J)**	**180.05 mons**	**08/05/27**	**25/02/41**
105	**Sector of 10 km (L-K)**	**180.05 mons**	**08/05/27**	**25/02/41**
122	**Sector of 10 km (K-J)**	**180.05 mons**	**08/05/27**	**25/02/41**
139	**Section of 20 km (D-E-F)**	**197.45 mons**	**08/05/27**	**27/06/42**
140	**Sector of 10 km (D-E)**	**197.45 mons**	**08/05/27**	**27/06/42**
157	**Sector of 10 km (E-F)**	**197.45 mons**	**08/05/27**	**27/06/42**
174	**Section of 20 km (J-I-H)**	**199.55 mons**	**08/05/27**	**26/08/42**
175	**Sector of 10 km (J-I)**	**199.55 mons**	**08/05/27**	**26/08/42**
192	**Sector of 10 km (I-H)**	**199.55 mons**	**08/05/27**	**26/08/42**
209	**Section of 10 km (F-G-H)**	**201.75 mons**	**08/05/27**	**25/10/42**
210	Survey surface network	9 emons	08/05/27	02/02/28
211	Civil Engineering	63.8 mons	02/02/28	22/12/32
212	Civil Engineering	63.8 mons	02/02/28	22/12/32
213	General infrastructure (lifts) - A	3 emons	26/12/34	26/03/35
214	**Sector of 5 km (F-G)**	**98.95 mons**	**26/03/35**	**25/10/42**
228	**Sector of 5 km (G-H)**	**98.95 mons**	**26/03/35**	**25/10/42**
242	**Installation of the Experiments (x2) - A-G**	**75 mons**	**26/03/35**	**24/12/40**
243	General services	46 emons	26/03/35	04/01/39
244	Detectors	24 emons	04/01/39	24/12/40
245	**Transfer line from B - Phase 2**	**62.25 mons**	**16/03/38**	**24/12/42**
255	**Transfer line from L - Phase 2**	**62.25 mons**	**16/03/38**	**24/12/42**
265	**Connection to LHC or SPS**	**57.9 mons**	**31/12/36**	**08/06/41**
266	**Connection to LHC or SPS from B**	**48.25 mons**	**27/09/37**	**08/06/41**
270	**Connection to LHC or SPS from L**	**48.25 mons**	**27/09/37**	**08/06/41**
274	End of LHC and SPS beam operation	0 mons	31/12/36	31/12/36
275	LHC or SPS RadioProtection cool-down	6 emons	31/12/36	29/06/37
276	LHC or SPS De-commissioning of the junction region	3 emons	29/06/37	27/09/37
277	LHC or SPS De-commissioning	18 emons	29/06/37	21/12/38
278	LHC or SPS Upgrade	30 emons	21/12/38	08/06/41

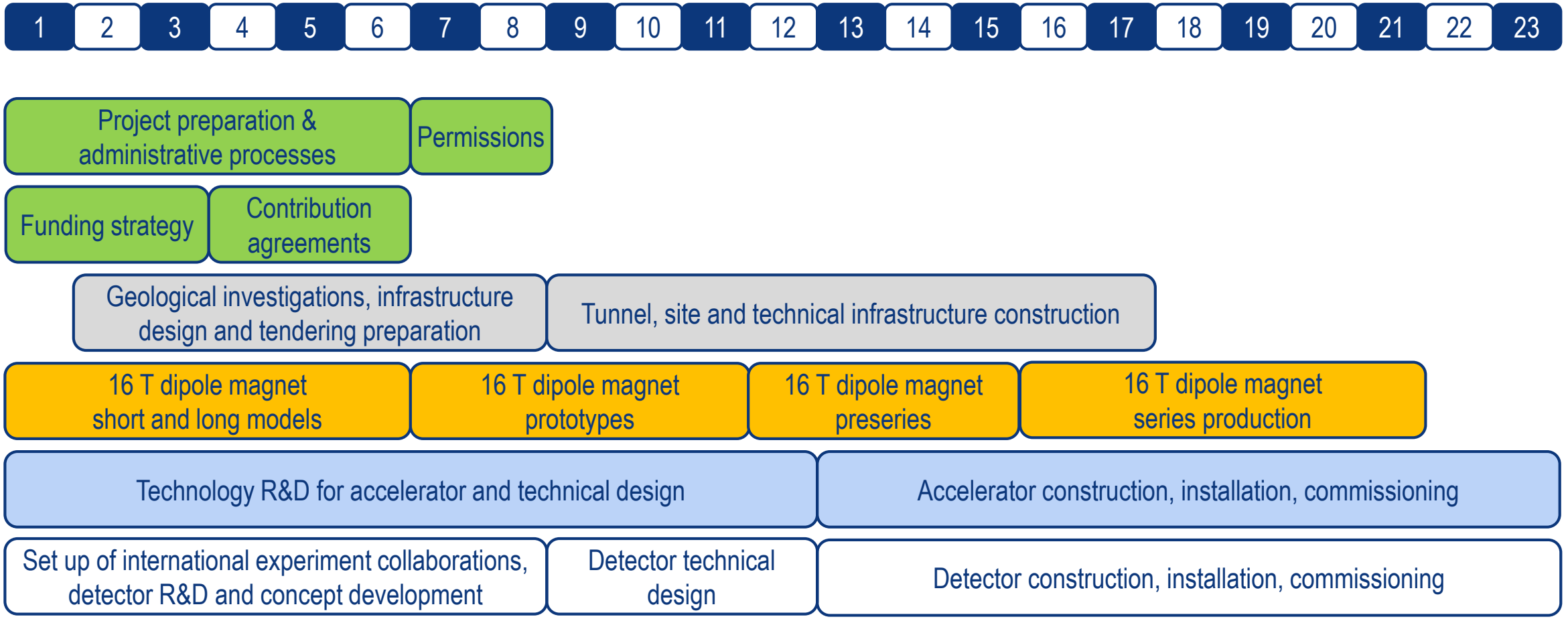


Example:
FCC-hh full installation plan

FCC-ee technical implementation schedule

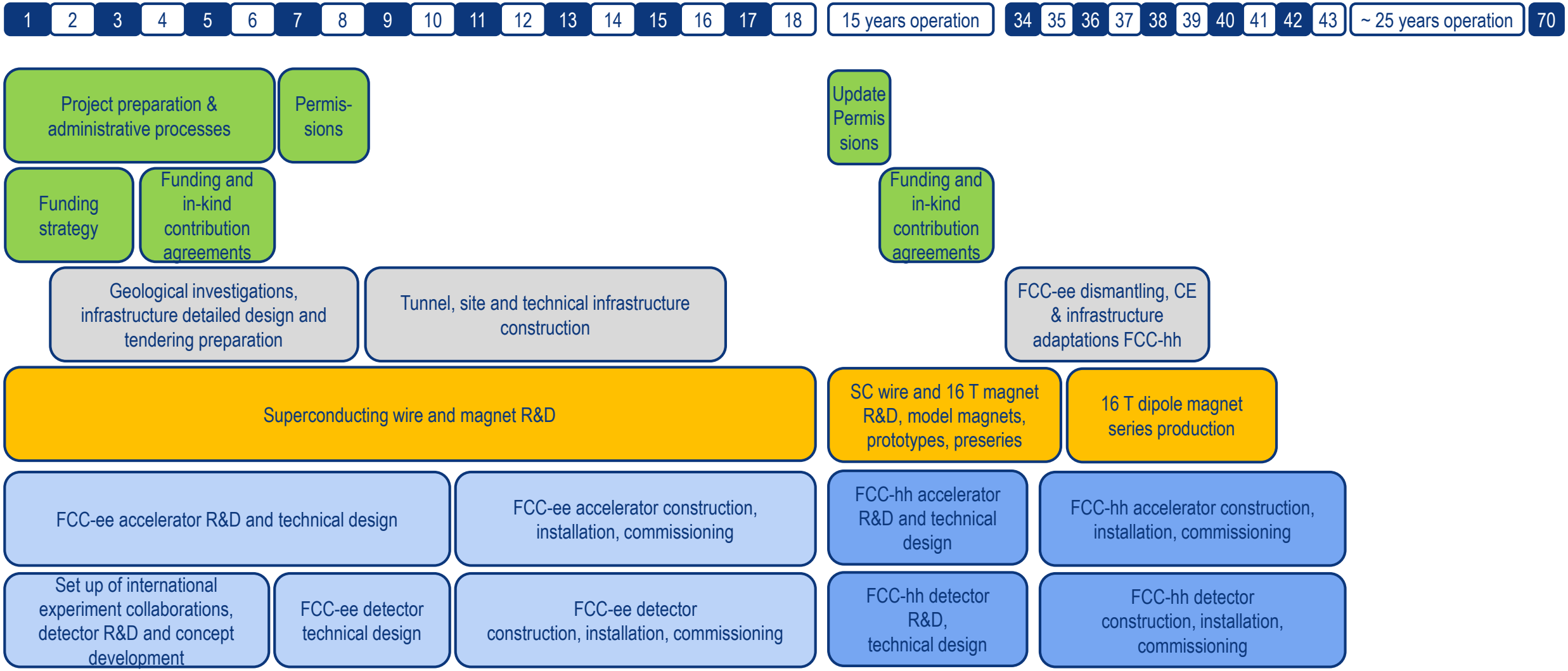


FCC-hh technical implementation schedule



- Assumes injection from (adapted) LHC.

FCC integral project schedule



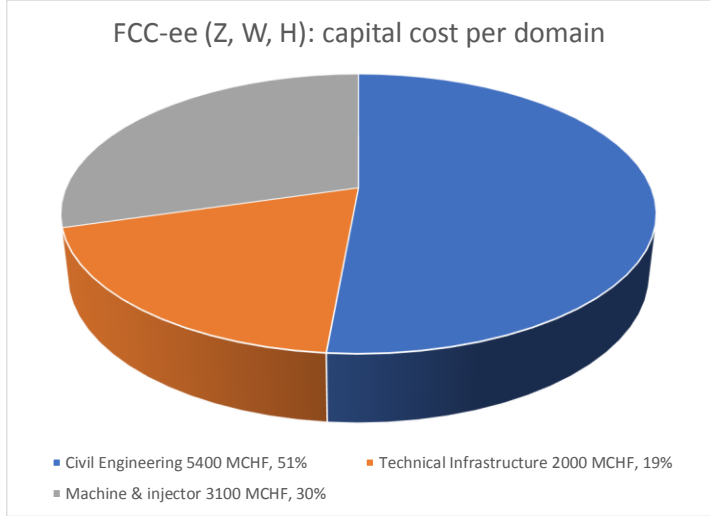
Input to cost estimates

- CE consultants cost study for complete CE construction (including access roads, spoil transport and removal cost, normalized with ~10 large European tunnel projects)
- Machine technical designs as available
- Scaling from LEP, LHC cost and HL-LHC, LIU activities
- Further input from other machines and research centres, e.g. SuperKEKB injector linac, etc.

FCC-ee cost estimate

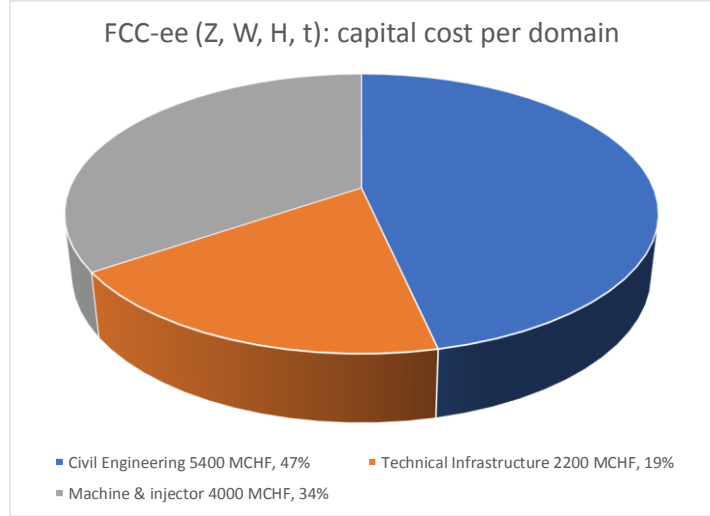
Total construction cost phase1 (Z, W, H) amounts to 10,500 MCHF

- 5,400 MCHF for civil engineering (51%)
- 2,000 MCHF for technical infrastructure (19%)
- 3,100 MCHF accelerator and injector (20%)



Complement cost for phase2 (tt) amounts to 1,100 MCHF

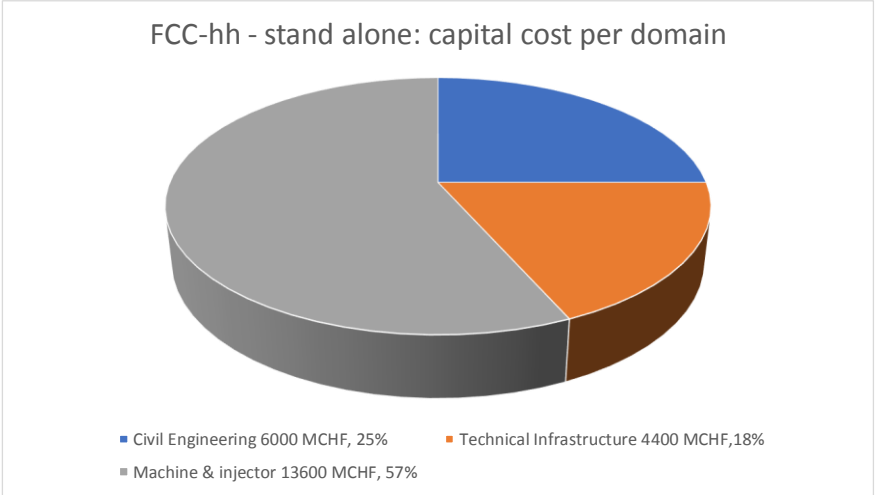
- 900 MCHF for RF, 200 MCHF for associated technical infrastructure



FCC-hh cost estimate

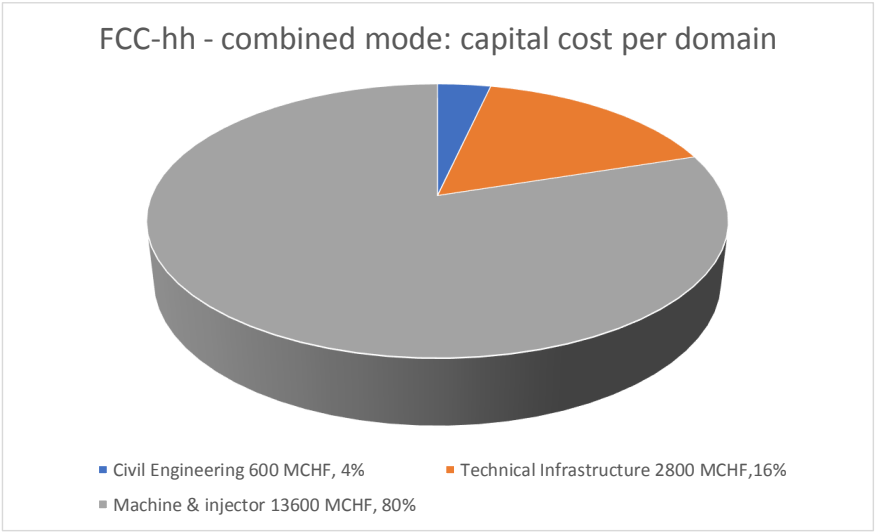
Total construction cost in "stand-alone" is 24,000 MCHF

- 13,600 MCHF accelerator and injector (57%)
  - Major part corresponds to the 4,700 Nb_3Sn 16 T main dipole magnets, totalling 9,400 MCHF, at cost target of 2 MCHF/magnet.
- 6,000 MCHF construction cost for surface and underground civil engineering (25%)
- 4,400 MCHF for technical infrastructures (18%)



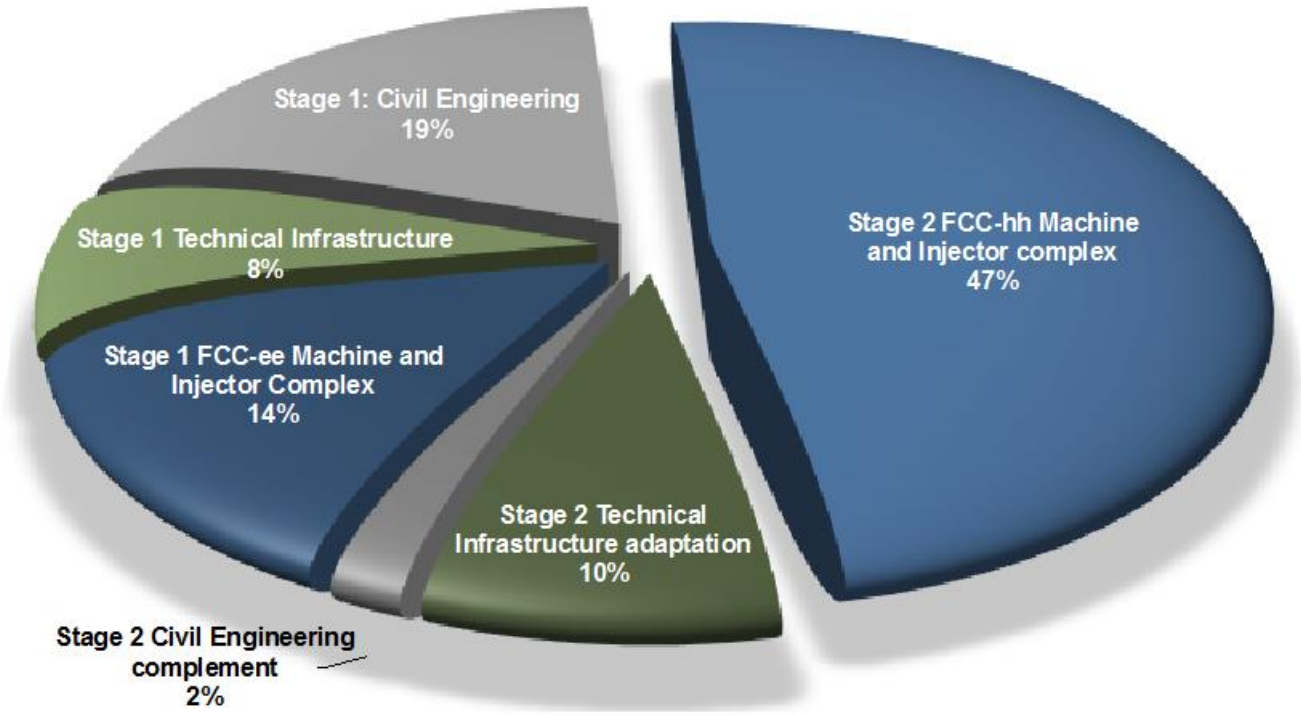
Total construction cost in "combined mode" following FCC-ee is 17,000 MCHF.

- CE and TI from FCC-ee re-used
- 600 MCHF for additional CE structures:
  - Two experiment caverns for the lower luminosity experiments
  - Beam dump tunnels and the two transfer lines from LHC
- 2,800 MCHF for additional TI, driven by cryogenics infrastructure



FCC-integrated cost estimate

Domain	Cost in MCHF
Stage 1 - Civil Engineering	5,400
Stage 1 - Technical Infrastructure	2,200
Stage 1 - FCC-ee Machine and Injector Complex	4,000
Stage 2 - Civil Engineering complement	600
Stage 2 - Technical Infrastructure adaptation	2,800
Stage 2 - FCC-hh Machine and Injector complex	13,600
TOTAL construction cost for integral FCC project	**28,600**



Conclusions and outlook

- The first phase of FCC conceptual design studies is completed. Baseline machine designs and associated infrastructures, with performance matching the physics requirements, were established.

- A possible integrated FCC programme has been developed and submitted to the ESU, together with descriptions of the individual machines.

- Next steps, in parallel to ESU process and in harmony with its recommendations, will develop a concrete local/regional implementation scenario in collaboration with host state authorities, accompanied by machine optimization, physics studies and technology R&D.